FLOOD RECONSTRUCTION OF 1st JANUARY 2020 STORM IN AN URBAN HOUSING AREA OF TANGERANG SELATAN, INDONESIA

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ABSTRACT:

The storm in the early hours on the first day of 2020 had recorded the highest intensity of rainfall since 1996. It deluged Jakarta as the capital city of Indonesia and the surrounding satellite cities which including Tangerang Selatan. An urban housing area in Tangerang Selatan, located adjacent to the Ciputat river is selected as study area. The area was affected by floods since the urban housing was established. The United States Environmental Protection Agency's Storm Water Management Model version 5.1 was used for finding out the hydrological and hydraulic problems. The model indicated that the flows from the sub-catchments did not contribute to cause flood. It was discovered that backwater effects occurred in the Ciputat river was the main cause of flooding. Thus, the existing drainage channels were overwhelmed by additional flow from the river.

Key-words: *Drainage, Reconstruction, Runoff rainfall, SWMM, Backwater.*

1. INTRODUCTION

An extraordinary storm on 1st January 2020, hitting Jakarta city had smashed the rainfall record in the Indonesian capital city for the last quarter-century. The intensity of rainfall was due to monsoon season and a high amount of water vapour in the air. It was recorded at least dozens had been killed and 60,000 displaced. Flash flood had occurred in several urban areas with flood depths ranged at 30-70 cm. The water level reading of the Ciliwung River that passes through the Jakarta city were reaching up to the level of 860 cm that indicated second-level alert status. About 75 percent of the houses close to the Ciliwung riverbanks, and 25 percent in the basin areas were flooded. The occurrence of the flooding was pointed to two factors, likely narrowing of the river and poor urban drainage. This can be proven from the early warning system in the downstream dam did not enter an alert status when the upstream effected area and its surroundings began to be flooded.

Flash floods are generally caused by excessive rainfall in a short and intensive-phase storm (Tarasova et al., 2019; Zanchetta and Coulibaly., 2019). It is relatively little in terms of the number of human deaths (Bryndal et al., 2017). Diakakis et al. (2019) had reported a flash flood in the urban area in Greece, known as a tragic disaster, had caused the loss of 24 people, making it the deadliest flood in a period of 40 years. Subsequently, Paprotny et al. (2018) reported that high flood losses in 37 European countries had prompted the creation of a new database of damaging floods since 1870. Barichivich et al. (2018) had reported that historical extreme flooding in the Amazon region was a combination of Atlantic warming and Pacific cooling. Akter et al. (2020) had reported that Chittagong city in Bangladesh experienced regularly flooding during monsoon seasons. Prior to this, Borga et al. (2014) presented that flash flood in the Italian Alps region, it was more frequent and destructive due to climate change.

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Urban drainage is a component in housing planning and one of the basic facilities designed to meet the needs of the community. As mentioned by Burian and Edward (2015), urban drainage is an important aspect that must be built for water and waste runoff media that must be well designed to accommodate rainwater and prevent flooding. As well, Patrick et al. (2019) defined a good drainage system should be able to accommodate as much water discharge as possible. So, if the water discharge exceeds the estimate planned at the initial stage, the drainage will accommodate poorly the function and drain it. It takes a few minutes to several hours for the floodwaters to drain and the rainwater returns to the sewers and the floodwaters are slowly subsided. Although it can be resolved in a short time, it causes inconveniences for instance traffic jams, property damage and some cases human lives (Mah et al., 2020). Besides, the increasing urban population that continues to increase in a relatively short time period, requires good facilities and infrastructure. An increasing population is followed by the amount of waste, both in the forms of garbage and liquid waste (Honingh et al., 2020). If it is not reinforced by an adequate drainage channel thus it will cause water overflowing the channel at times of high flow events. Apart from water conveying, the drainage is also used for bathing, washing, cooking and other human activities (Wu et al., 2020).

Storm Water Management Model (SWMM) is a drainage modelling platform, in which the model could simulate and observe flooding in urban areas (Akter et al., 2020). As identified by Mah et al. (2019), SWMM version 5.0 was used to conduct modelling of a residential-based drainage system that incorporated with a stormwater detention system. Conversely, Al Dianty (2020) used SWMM to find effective drainage using the Bio pore Infiltration Hole (LRB) that was built in an urban area to absorb a flood discharge of about 0.3282 m^3/s. This model simulated the conditions and natures of the infiltration to calculate the discharge of flood in eight rain events in urban areas, hence, to prevent extreme rainstorms (Bai et al., 2019). As well, Arjenaki et al. (2020) used SWMM to test Low Impact Development (LID) measures subjected to hydrological analyses in return periods of 2, 5, and 10 years

This research is intended to do SWMM simulation and thereafter evaluation of the tremendous flooding of 1st January 2020 in an identified effected urban area. Furthermore, the direction of the research is to perform the assessment on the suitability between discharge and volume of drainage channels which is recommendatory for solving the urban drainage problems (Brown and Borst., 2016; Akter et al., 2020; Al Dianty., 2020).

2. MATERIALS AND METHODS

2.1. Study Area

An urban housing area located in Ciputat District, Tangerang Selatan, Indonesia was identified as study area (**Fig. 1**). Residents of the area have been suffering from repeating flood. The drainage conditions in the area are no longer able to drain runoff effectively into the existing drainage system. The drainage conditions and dimensions of the urban housing drainage channel are depicted in **Table 1** and **Fig. 2**.

The urban housing area has ± 600 units of houses with an area of ± 15.44 ha. Flooding in the area was recorded in January 2013, January 2014, and most recently, January 2020. Reconstruction of the January 2020 flood was done during the pandemic Covid-19 period. The data were collected and prepared through direct observation, interviews, field survey on the characteristics of housing area conditions, infrastructure, existing drainage, and road conditions.

The variables used in the study included (1) physical conditions of drainage (drainage plan, channel conditions and network patterns), (2) Non-physical conditions (community behaviours and related governance), (3) Basic physical conditions of the area (slope, length, width, and rainfall data on January 1, 2020).

Fig. 1. Map of study area.

Fig. 2. Drainage condition.

Table 1.
Dimensions of the urban housing drainage channel.

Type	Width (m)	Depth (m)
A	2	1.5
B	0.5	0.7
C	0.3	0.4

2.2. Intensity of rainfall

The intensity of rainfall is the input value in the form of time series, in which the Monobe Formula is used to calculate the concentration-time in each existing channel. The relationships between intensity, duration of rain and frequency of rain is usually expressed in terms of the Intensity-Duration-Frequency (IDF) curve as in Equation 1:

$$I = \frac{R_{24}}{24}\left[\frac{24}{t_c}\right]^{\frac{2}{3}} \quad \textbf{(1)}$$

where
I = intensity of rainfall (mm/hr);
R_{24} = maximum daily rainfall for 24 hours (mm);
t_c = time of concentration (s).

2.3. Rainfall Hyetograph

Rainfall hyetograph is a histogram of rainfall with intervals of time as abscissa and rain depth as ordinate. The hyetograph data are inputted into the SWMM model for drainage modelling. While beforehand, the Alternating Block Method (ABM) is a simple way to create a hyetograph plan from the IDF curve (Yen and Chow, 1980). The method is designed for the distribution of average rainfall intensity over time of storm. The hyetograph produced by this method is the rain that occurs in n series of consecutive time intervals with a duration is 1 hour for time Td = n x Δt. Where tc is the intensity of rainfall for the 24 hours of the yearly period in Eq.2. Finally, the hyetograph is ordered like a triangular curve.

$$Hyetograph = t_c\,.it \quad \textbf{(2)}$$

where
t_c = time of concentration (s).
it = Intensity R_{24}

2.4. Drainage Modelling

SWMM drainage modelling was started with sub-catchment analysis. It was carried out by using Google Earth, considering several variables such as area (in hectares), lowest elevation, highest elevation, width, and % slope. The Google application assisted in determining the total area, sub-catchment area, pervious and impervious coverage. Water tightness in each sub-catchment was investigated so that the land use was designated as a settlement and the concrete lining was about 15%. The hyetograph data mentioned above was inserted to the rain gauge interface as a provider of precipitation data for one or more sub-catchments in the study area. The type of rain gauge was specified. Then, junctions were digitized into the modelling platform where these were to display the connections of the channels. It also displayed the meeting of the artificial channel with the natural channels such as a river or stream. Data like the length of the main channel was taken from Google Earth, which was presented in 80 junctions and one outfall. Next, links were digitized to represent conduits for the water flows and the variables such as shape, maximum depth, length, and roughness. The links had different properties, depending on the site conditions. These links were connected by junctions in each existing sub-catchment. We used a value of 0.02 for the conduit's roughness coefficient because generally, most conduits are made of concrete that had rough surfaces on the conduits. The SWMM's hydraulic simulation engine was based on Manning equation (Bellos et al., 2018). It was a function of relationships between discharge (Q), cross-sectional area (A), circle radius (R), and slope (S). Furthermore, it could perform checking on drainage capacity. If it predicted a conduit was flooded, it means that the capacity of the conduit was unappropriated. In this regard, the dimensions of the conduit was modified and the simulation was reran until an appropriate dimension was found.

3. RESULTS

3.1. Determination of Rainfall Intensity

The calculation was carried out by processing the maximum amount of rainfall intensity on 1st January 2020 which was found as 377 mm/hr. It was designed as daily rainfall in **Table. 2**. As identified by Al Dianty et al. (2020), the shorter of the rainfall, the higher the intensity of rainfall as well as the greater of return period, the higher the intensity of rainfall.

Table 2.

Intensity of rainfall.

Time (Hour)	R24	Time (Hour)	R24
	377 mm/hour		377 mm/hour
0.116	431.557	11	26.425
0.231	271.864	12	24.935
0.347	207.471	13	23.640
0.463	171.264	14	22.500
0.578	147.591	15	21.489
1	130.699	16	20.584
2	82.335	17	19.768
3	62.833	18	19.029
4	51.868	19	18.356
5	44.698	20	17.739
6	39.583	21	17.171
7	35.717	22	16.646
8	32.675	23	16.160
9	30.207	24	15.708
10	28.158		

3.2. Determination of Rainfall Hyetograph

Based on ABM mentioned in Section 2.3, the peak hyetograph was found at 71.926 mm, as well presented in **Fig. 3**. It represented the characteristics of an extreme flood. The method that was demonstrated here endorsed a synthetic hyetograph in a dimensionless form in different durations, as reported by Ellouze et al. (2019).

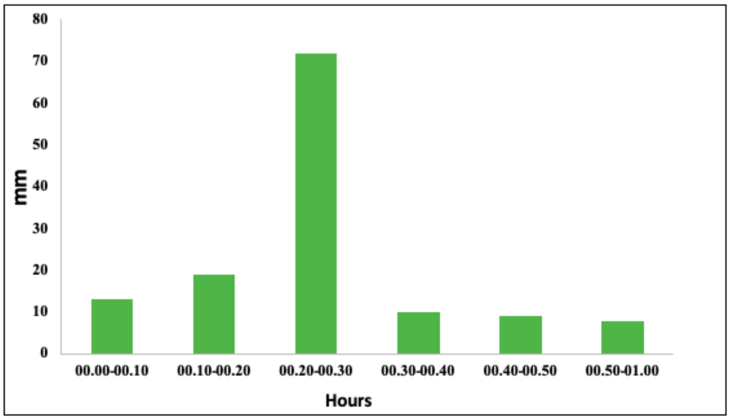

Fig. 3. Rainfall Hyetograph.

3.3. SWMM Modelling Outcomes

The drainage modelling was carried out after the hydrological analysis and hydraulic process were completed. The study area was divided into 43 sub-catchments, while the drainage system was represented in 80 junctions, 80 conduits and 1 outfall. The big number of the mentioned components was to mimic the actual values in the study area as much as possible. Furthermore, to run the simulation, an error rate should be less than 10%. The developed SWMM model was found with an error value about -0.51% for surface runoff and -0.02% is for flow routing. The results of the simulation indicated that the drainage channels are still capable to accommodate the runoff. It can be observed in **Fig. 4**. On another note, there was high peak runoff from the surface runoff in **Fig. 5**.

The peak runoff that occurred in the 4th hour in the sub-catchment 1 until sub-catchment 43 was estimated at 0.09 m^3/s (**Fig. 5**). while the maximum simulation occurred in the first hour where it is 0.02 m^3/s**.**

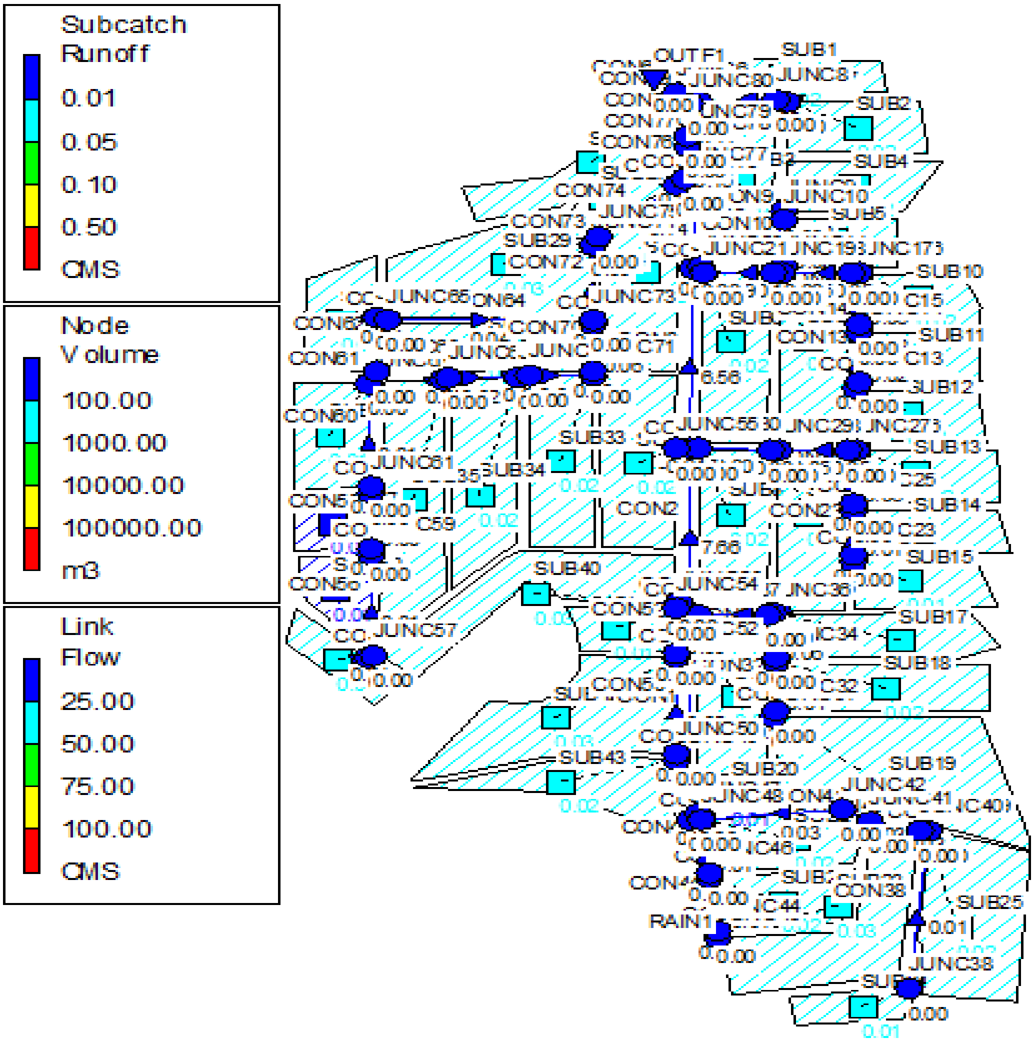

Fig. 4. Sub-catchment Simulation Area.

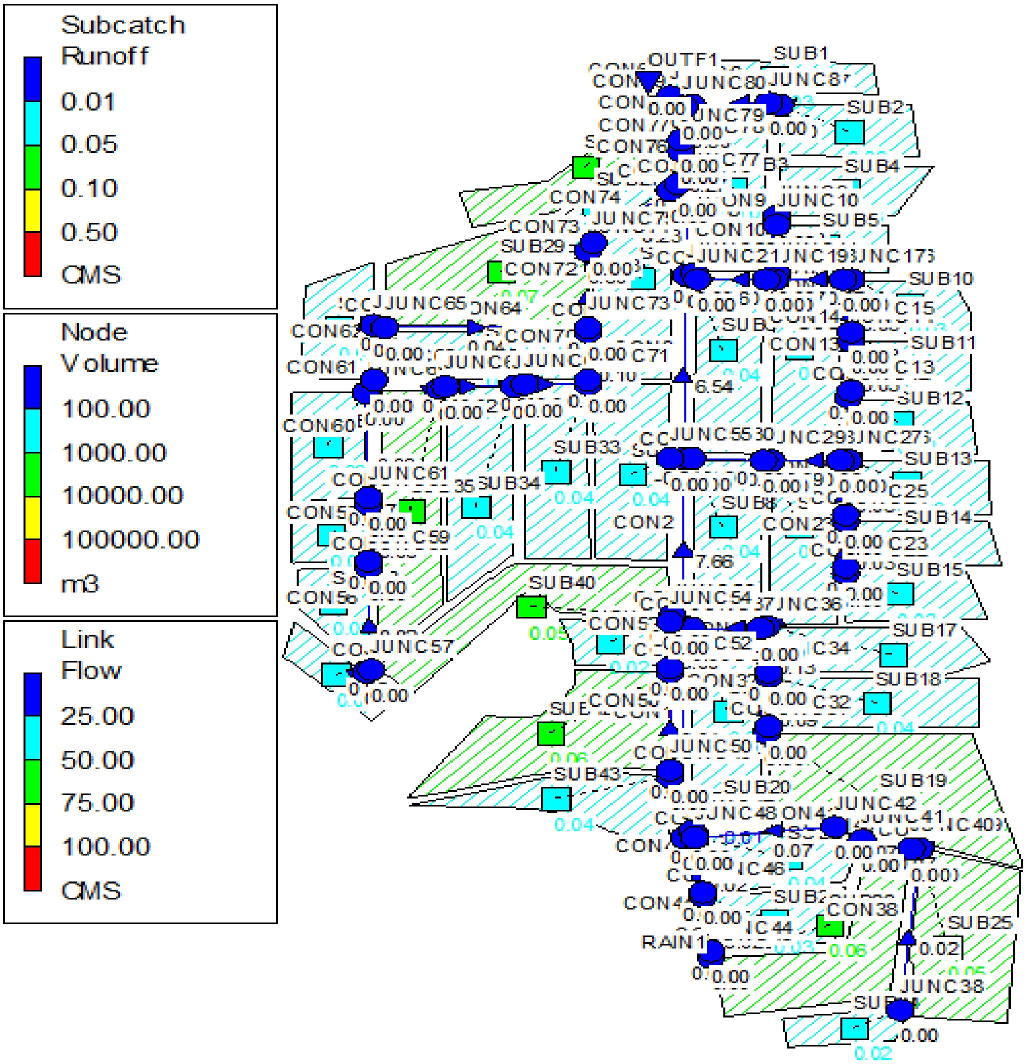

Fig. 5. Runoff Sub catchment.

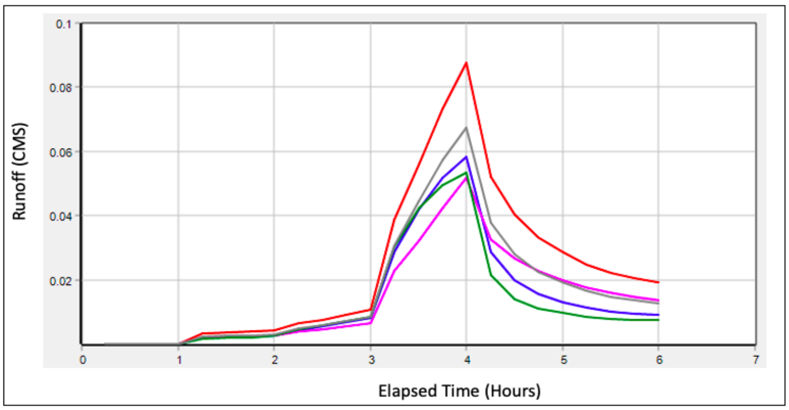

Fig. 5. Runoff Simulation.

The simulation was continued on 15th minute – 40th minute runoff flow for long node junction namely junction 1, junction 2, junction 3, junction 4, junction 5, junction 6, and outfall 1, it is presented in **Fig. 6**. It was done after obtaining runoff discharge from each existing sub-catchment. The dimensions used in the simulation were about 2-meter width and 1.5-meter depth. The highest water level occurred between 35th and 40th minutes was about 50 cm. It was found that the runoff flow in the main channel was not fully filled.

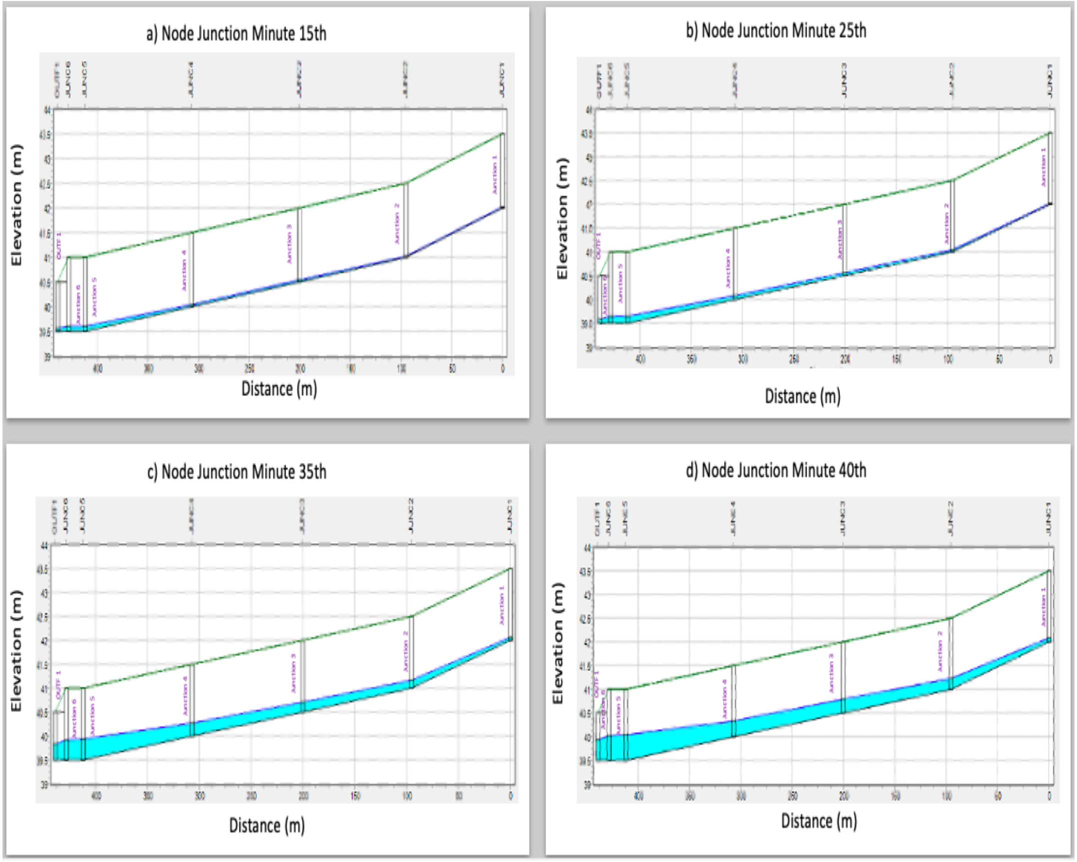

Fig. 6. Long node junction at minute 15th – 40th.

3.4 Discussion

The condition of the drainage channel greatly affects the smooth flow of water, if there is a blockage in one of the drainage networks, there will be a reduction of water storing capability in the drainage channels. Therefore, the authors focus on the active processes of the urban flash floods through analysis and simulation modelling. The site surveys did not find anything that could disrupt the water flow in the existing drainage channels. However, photographs taken during the 1st January 2020 flood event showed there were overflow in main channel junctions 1 and 2 (**Fig. 7**).

As explained by Mahmodian (2018), urban drainage modelling needed the development of sophisticated simulators due to the various underlying surfaces and drainage processes. Zhou et al. (2016) demonstrated the flood simulation models required a four-step phases, namely (1) selection of roughness zones; (2) generation of synthetic data from water depth, flow, velocity, and roughness height combinations; (3) calculation of shear stresses using a physically based equation; and (4) estimation of the model parameters through regression.

Whilst other key aspects of modelling were discussed by Tarasova et al. (2019) who had justified multicriteria approaches which were needed seasonal classifications between effects and causative mechanisms. Meanwhile, the recent modelling distinguishes Mignot et al. (2020) by laboratory probation in a single street intersection, surface-sewer exchanges, the array of obstacles and quasi-realistic urban districts.

Fig. 7. Floodwater Overflow taken on 1st January 2020.

Fig. 8. Backwater in Ciputat River taken on 1st January 2020.

The site surveys also did not find any illegal buildings along the Ciputat river. Therefore, there was no modification to the natural waterways that could invite flooding. Regarding the natural waterway modification, Haidu and Ivan (2016) demonstrated Digital Terrain Model and Digital Surface Model to examine the trend of increasing runoff volume. While Gibson et al. (2016) highlighted Cellular Automata (CA) as a simulation method based on an ordinary square grid, thereby saving set-up time for configuring terrain data into irregular triangular nets for urban surface flooding modelling.

Another discovery was coming from Ciputat river. The reduction of drainage dimensions had contributed to backwater effects in the main channel where it entered junction 1 until junction 6 towards the outfall shown in **Fig.8**. The back water has caused the existing branches and the storage channel could not drain the water because the trunk condition was full. This evidence showed the main channel of drainage was not enough to accommodate runoff from the sub catchment. In this situation, we proposed to perform urban drainage management. Bermudez et al. (2018) challenged the idea by real-time 1D-2D dual drainage model in terms of peak surface flood volume and maximum flood.

5. CONCLUSIONS

The flash flood on 1st January2020 was recorded as the worst disaster of an urban housing in Tangerang Selatan, Indonesia since it was established. The maximum intensity of rainfall was about 377 mm/hr. The channel could not hold the backwater therefore no longer adequate to accommodate runoff from the sub-catchments. The result of main drainage connected by junction 1 until junction 6, there was no visible overflow on the channel. Likewise, other junctions that connect the branch and collection of conduits. Nevertheless, the modelling outcome showed the channel will be fully charged in the 35t^{h} and 40th minutes. The founding was based on the condition of the main channel was full; thus, the branches and connecting channels were obstructed to discharge water flow to the main channel. The rainfall-runoff problem can be controlled through a proper and adequate drainage system. Moreover, additional modelling of urban water management recommended to use for simulation comparison. The drainage system should have abilities to keep the areas from backwater, control the runoff, control channel surface wastewater due to the accumulation of rainfall-runoff.

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